

Isoëtes hawaiiensis: A Previously Undescribed Quillwort from Hawaii

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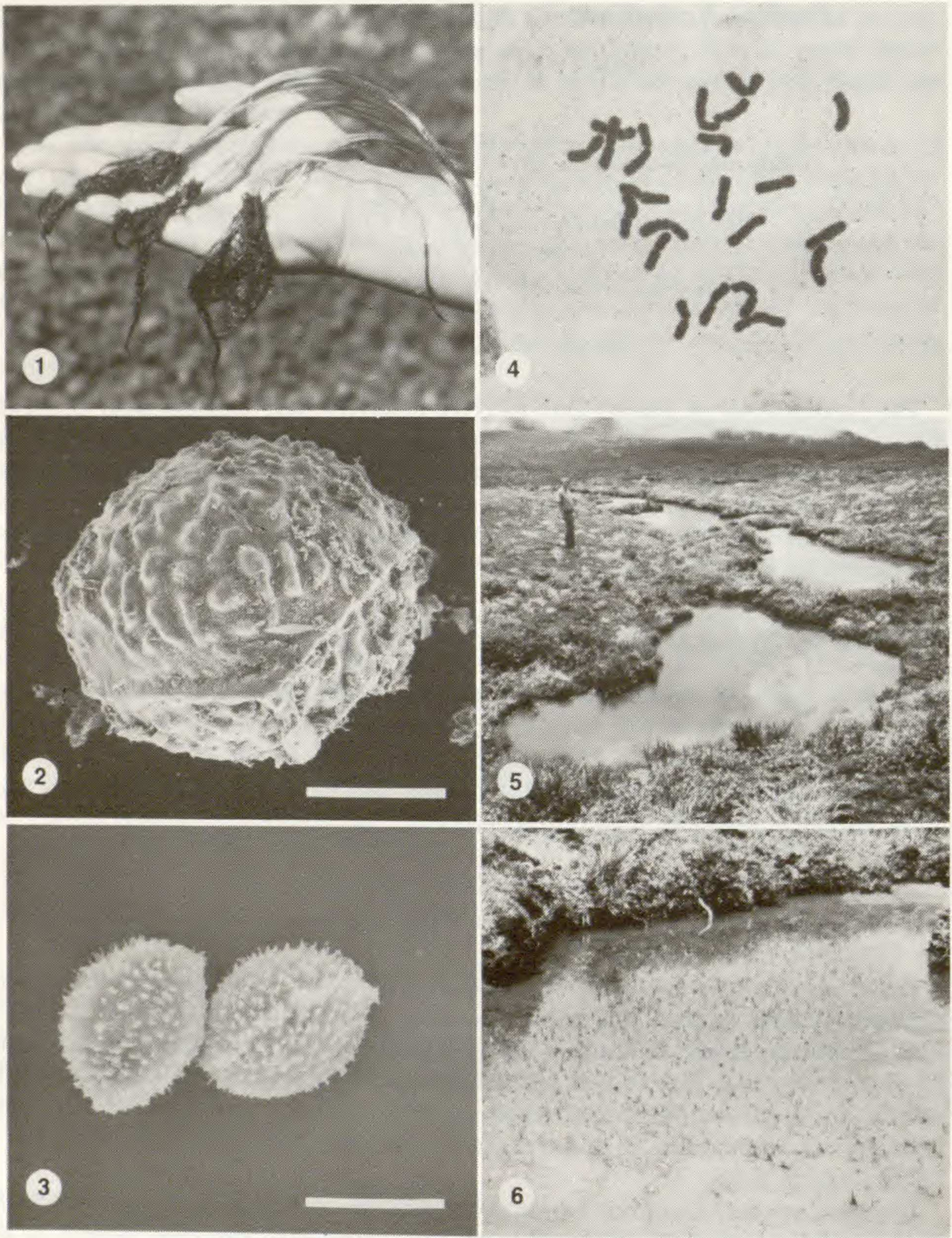
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The pteridophytes of Hawaii have received relatively little attention from botanists during the past half-century. However, intensive recent studies in the islands have revealed a number of previously undescribed species, including the quillwort named here. Quillworts have been found in Hawaii several times since early this century. Between 25 September and 17 October 1917, Charles N. Forbes discovered *Isoëtes* from pools atop Mt. Eke on the island of Maui (*Forbes 682. M. BISH*). Forbes did not recognize his collection to be *Isoëtes*. It was not until 17 October 1977, when F. R. Warshauer collected *Isoëtes* from the east slope of Mauna Kea on the island of Hawaii (*Warshauer & McEldowney 1500 BISH*), that Hawaiian botanists realized there was a native quillwort in the flora. Robert W. Hobdy again discovered *Isoëtes* in pools on the summit of Mt. Eke on 23 October 1980 (*Hobdy 931 BISH*), and he collected it once more from the same site on 21 October 1982 (*Hobdy 1705-1710 BISH*). Study of these specimens and three later collections from Mt. Eke (*Taylor 5332, 5658 MIL* and *Palmer 672 BISH*) indicates that these Hawaiian quillwort acquisitions represent a previously undescribed species of *Isoëtes*.

Isoëtes hawaiiensis W. C. Taylor & W. H. Wagner, sp. nov. – HOLOTYPE: Maui, pools, Mt. Eke, *Forbes 682. M.*(BISH).

Planta aquatica, emergens. Caudex brunneus, subglobosus, cylindricus, vel fusiformis, bilobatus. Radices amplae, implexae. Folia vivide viridia, basin versus pallida, semper-virentia, gracilia, usque ad 25 cm longa, \pm dimidio tegens. Sporangium subglobosum $\pm 2-3$ mm diametro, pariete non pigmentifero, $\pm 10-20$ megasporas vel numerosas microsporas continens. Megasporae albae, 475–650 μm diametro, obscure vel manifeste rugulosae vel tuberculatae. Microspora pallide brunneae, 30–40 μm longae, spinulosae. $2n=22$ (Figurae 1–4).

Emergent aquatic. Rootstock brown, subglobose to cylindrical or fusiform, bilobed. Roots extensive, matted. Leaves bright green, pale toward base, evergreen, slender, up to 25 cm long, ± 1 mm in diameter, abruptly dilated toward base to accommodate sporangium, gradually tapered to apex, spirally arranged, flaccid. Velum overlaying $\pm 50\%$ of adaxial wall of sporangium. Sporangium subglobose, $\pm 2-3$ mm in diameter, wall unpigmented, containing $\pm 10-20$ megasporas or numerous microspores. Megasporas white, 475–650 μm in diameter, with obscurely to boldly rugulate or tuberculate texture. Microspores light brown, 30–40 μm in length, with spinulose texture. $2n=22$ (Figs. 1–4).



Figs. 1–6. *Isoëtes hawaiiensis* plants, spores, chromosomes, and habitats. Fig. 1. Three plants of *I. hawaiiensis* from pools on Mt. Eke. Fig. 2. SEM photomicrograph of an *I. hawaiiensis* megaspore showing rugulate texture. Bar scale = 240 μm . Fig. 3. SEM photomicrograph of two *I. hawaiiensis* microspheres showing echinate texture. Bar scale = 24 μm . Fig. 4. Brightfield photomicrograph of *I. hawaiiensis* chromosomes in a single cell of a root tip squash. Chromosomes stained with Wittman's hematoxylin. Fig. 5. Shallow ponds on summit of Mt. Eke containing *I. hawaiiensis*. Fig. 6. *I. hawaiiensis* rooted in the soft mud bottom of a Mt. Eke pond.

Presently, *Isoëtes hawaiiensis* is known only from the top of Mt. Eke on the island of Maui and from the east slope of Mauna Kea on the island of Hawaii.

Mt. Eke, a peak on the northeast side of the West Maui Mountains, is shrouded in nearly perpetual mists at 1375 m elevation. Annual precipitation is estimated to be about 6000 mm. Mt. Eke's summit is the remnant core of a volcanic trachyte dome, roughly circular in shape and flat topped. Low growing bog vegetation covers most of the mountain top except where irregularly shaped shallow ponds occur (Fig. 5). The forty-seven ponds on the summit of Mt. Eke total about 0.4 hectares in area, harbor approximately 100,000 individuals of *I. hawaiiensis*, and appear to be the only habitat for *Isoëtes* in this region. Although the shallow ponds on Mt. Eke appear to hold water most of the time, some of the ponds occasionally are without standing water. Similar ponds at higher and lower elevations in the montane bogs of west Maui have not been observed to contain *Isoëtes*. On Mt. Eke, *I. hawaiiensis* grows in the soft mud bottoms of the ponds. Plants form loose clumps composed of 10–15 individuals with their roots intertwined and matted. From a distance, these aggregations give the impression of a sparse lawn (Fig. 6). The largest plants occur in water averaging 8–10 cm deep. The pond margins, which are most subject to periodic drying, are usually devoid of *Isoëtes*.

The known populations of *I. hawaiiensis* on the east slope of Mauna Kea are located in two adjacent stream channels within a montane rainforest at about 850 m elevation, approximately 17 km northwest of Hilo. At this location, about 50 to 100 plants grow close together in several patches attached to lava rock forming the stream courses. Annual precipitation in this area is estimated to be about 7600 mm.

Noteworthy features of *I. hawaiiensis* are its polymorphic rootstock and its extensive, matted roots. Rootstocks of *Isoëtes* are usually uniform in shape for a particular species. However, rootstocks of *I. hawaiiensis* may grow a centimeter or more either horizontally to become fusiform or vertically to become cylindrical. Occasionally, cylindrical rootstocks are dilated distally and are clavate, clavately lobed, or variously lobed. Roots of *I. hawaiiensis* are slender, numerous, and often longer than the rest of the plant. Such extensive roots are probably needed to anchor plants securely in soft mud. These roots are intertwined and tangled when plants are lifted from their substrate.

Isoëtes hawaiiensis is a basic diploid species. It appears to have evolved through the isolation and genetic divergence of plants brought from a distant continent or island. Progenitors of *I. hawaiiensis* possibly arrived on Hawaii as spores deposited from the bodies of migratory waterfowl. For example, the Mallard is known to eat *Isoëtes*. This duck occasionally reaches the Hawaiian Islands presumably from its breeding grounds in western North America (Berger, 1981, p. 227–233). The Canada Goose, which also has been observed to devour *Isoëtes*, is an irregular visitor to the Hawaiian lowland wetlands. While North American origins for *I. hawaiiensis* are plausible, they do not seem likely for at least two reasons. First, western North American species of *Isoëtes* appear to be quite different from *I. hawaiiensis*. Second, there are no records of ducks or geese frequenting Mt. Eke or the west forest summits in the Eke region.

It seems more likely a progenitor of *I. hawaiiensis* could have come from the *I. taiwanensis* complex. The *I. taiwanensis* complex is a group of high elevation, cold water, island species occurring along the western Pacific rim from New Zealand to Taiwan (Britton & Brunton, 1991). For example, like *I. hawaiiensis*, *I. taiwanensis* is a basic diploid. It also has rugulate megaspores and echinate microspores. Furthermore, *I. taiwa-*

nensis occurs in a small, shallow pond on northern Taiwan near the top of an extinct volcano at an elevation of about 1000 m (DeVol, 1972). Whereas *Isoëtes taiwanensis* is distinguishable from *I. hawaiiensis* by its lack of a velum, trilobed corm, and smaller megaspores and microspores which average less than 400 μm in diameter and less than 30 μm in length, respectively, *I. taiwanensis* is similar to *I. hawaiiensis* in chromosome number, spore textures, and habitat. An ancestor of *I. hawaiiensis* from the *I. taiwanensis* complex could have reached the Hawaiian Islands via the Pacific Golden Plover which winters from India, China, Taiwan, and the Hawaiian Islands south to Australia, New Zealand, Samoa, and Oceania. In spring this plover migrates to its breeding grounds on the tundra of northern Siberia (Johnsgard, 1981, p. 135). The Pacific Golden Plover is an abundant visitor to Hawaii and it frequents the shallow pools on Mt. Eke where *I. hawaiiensis* grows (Berger, 1981, p. 231).

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